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Minimization of CO & CO_2 from Exhaust of Two Wheeler Motorcycle

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Abstract: Global warming and global climatic changes resulted from anthropogenic CO_2 emissions has become the main issue recently. Since, the beginning of industrial revolution, the concentration of CO_2 has increased more than 30% in the atmosphere, and resulted in various catastrophic occurrences. Our research is focused on decreasing the level of CO2 from exhaust gases of a Two-Wheeler or Motorcycle by adsorption technology. The adsorption is carried out in an adsorber like device containing a bed of charcoal through which the exhaust gases are passed. After adsorption we found a significant amount of CO2 reduction from exhaust gases with an excellent bed's efficiency. The type of CO2 adsorption is reversible that is physical adsorption is observed. The saturated bed of charcoal is again recharged or dumped as a fertilizer in the field to increase crop yield.

Keywords: Global warming, anthropogenic CO2, catastrophic, exhaust gases, two wheeler motorcycle, adsorption, adsorber, physical adsorption.

I. INTRODUCTION

I. CO_2 Emissions and Its Adverse Effects on Environment: Global warming**:** - A gradual increase in the overall temperature of the earth's atmosphere generally attributed to the greenhouse effect caused by increased levels of carbon dioxide, CFCs and other pollutants.

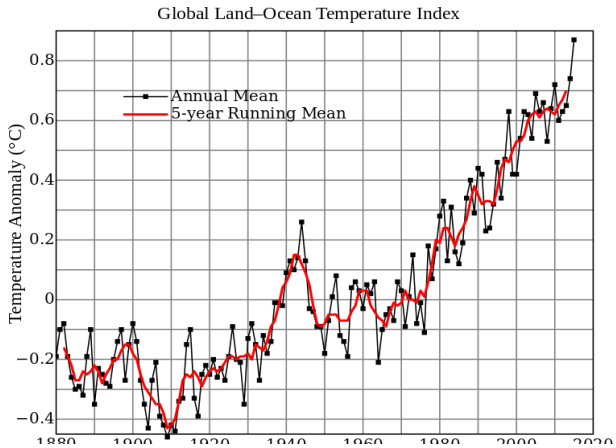

Fig. 1. Global Land-Ocean Temperature Index. [20]

Vehicle emissions can affect the environment in several ways. Cars and motorcycles emit greenhouse gasses, such as carbon dioxide, which contribute to global warming. Some air pollutants and particulate matter from these can be deposited on soil and surface waters where they enter the food chain; these substances can affect the reproductive, respiratory, immune and neurological systems of animals.

CO_2 is the primary anthropogenic greenhouse gas, accounting for 77% of the human contribution to the greenhouse effect in recent decade (26 to 30 percent of all CO_2 emissions). Main anthropogenic emissions of CO_2 come from the combustion of fossil fuels. The emission of carbon dioxide to the atmosphere has been identified as a major contributor to global warming.

Sources of carbon dioxide are divided into two categories: natural source and human source. Main human source is the combustion of fossil fuels such as coal, natural gas or petroleum, and industrial processes such as power plants, oil refining and the production of cement, iron and steel. Since the beginning of the industrial age in 1800 A.D., the carbon concentration in atmosphere has increased from 280 to 390 ppm in 2010.

Human activities are a major cause of increased CO_2 concentration in atmosphere, as in recent decade, two-third of greenhouse effect was caused by human activities. Various technologies recently used for CO_2 capture include: absorption, adsorption, cryogenic distillation, and membrane separation.

II. EFFECTS OF GLOBAL WARMING ON ENVIRONMENT

1) As climate changes, the probability of certain types of weather events are affected. Changes have been observed in the amount, intensity, frequency and types of precipitation in Rain.

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2) The cryosphere is made up of areas of the earth which are covered by snow or ice. Observed changes in the cryosphere include declines in Arctic sea ice extent, the widespread retreat of alpine glacier and reduced snow cover in the Northern Hemisphere.
3) The oceans serve as a sink for carbon dioxide, taking up much that would otherwise remain in the atmosphere, but increased levels of CO_2 have led to ocean acidification. Furthermore, as the temperature of the ocean increases, they become less able to absorb excess CO_2.
4) Amount of oxygen dissolved in the oceans may decline with adverse consequences for ocean life.

III. EXHAUST EMISSION FROM TWO AND THREE WHEELER VEHICLES

Worldwide, motorcycle usage is increasing at a rapid pace, especially in the urbanized areas of Asia. Approximately 200 million motorcycles are estimated to be in use and this number is growing at a rapid rate, especially in Asia, where the average annual rate of growth for the region is 15%, with annual growth rates at or above 5% in most Asian countries. The majority of these vehicles are powered by two-stroke engines. Two-stroke engines have very high exhaust emissions. The large population of two-wheel vehicles accounts for a significant portion of global mobile source hydrocarbon (HC) and carbon monoxide (CO). NO_x emissions from two-stroke engine vehicles are relatively small compared to other mobile sources. Confronted with the need to address deteriorating air quality, a growing number of countries worldwide have implemented, or are in the process of implementing, programs to substantially reduce gaseous emissions from spark-ignition (SI) two-wheel vehicles. In making pollution control decisions, countries in the North America, Asia and Europe, are considering a number of issues such as the levels of three mission standards to implement as well as the types of control strategies that should be required.

Motorcycle populations are sensitive to geography and economic prosperity and, therefore, their populations are very significant in many areas of the world. Motorcycles outnumber four-wheel vehicles in a number of Asian countries and growth in motorcycle population is dramatic. Asia accounts for almost 85% of new motorcycle sales and, because of comparatively lower Asian per capita automobile and truck ownership, air quality in Asia is substantially more sensitive to motorcycle emissions impacts than non-Asian cities. Motorcycle emissions are estimated to contribute as much as 40% of PM and CO_2, 50% of CO, and 70% or more of volatile organic compounds (VOCs) in some Asian cities. The majority of the global motorcycle population uses small displacement engines, generally 50 to 150 cc, which complicates emission control issues due to the low cost, space limitations, and simple design characteristics of small engine technology. [5]

IV. CONCEPT OF ADSORPTION

A. What is Adsorption?
Adsorption is the phenomenon of accumulation of large number of molecular species at the surface of liquid or solid phase in comparison to the bulk. [1]

B. How Adsorption occurs?
The process of adsorption arises due to presence of unbalanced or residual forces at the surface of liquid or solid phase. These unbalanced residual forces have tendency to attract and retain the molecular species with which it comes in contact with the surface. Adsorption is essentially a surface phenomenon. [1]
Adsorption is a term which is completely different from Absorption. While absorption means uniform distribution of the substance throughout the bulk, adsorption essentially happens at the surface of the substance. When both Adsorption and Absorption processes take place simultaneously, the process is called sorption.
Adsorption process involves two components Adsorbent and Adsorbate. Adsorbent is the substance on the surface of which adsorption takes place. Adsorbate is the substance which is being adsorbed on the surface of adsorbent.

$$\text{Adsorbate} + \text{Adsorbent} \leftrightarrow \text{Adsorption} + \text{Desorption}$$

C. Adsorption in solids
In case of solid state these residual forces arises because of an unbalanced valence forces of atoms at the surface. The generation of these forces on solid surface can be explained diagrammatically as follows:
Due to cleavage of a big crystal into smaller unit, residual forces or vacancies gets generated on the surface of the solid. Occupancy of these vacancies by some other molecular species results into Adsorption. [1]

D. Facts about Adsorption Process: -

- Adsorption is a spontaneous process: - For reaction or process to be spontaneous, there must be decreases in free energy of the system i.e. ΔG of the system must have negative value.

Also we know,

$$\Delta G = \Delta H - T\Delta S$$

And during this process of adsorption, randomness of the molecule decreases which ΔS is negative. We can rewrite above equation as

$$\Delta G = \Delta H + T\Delta S$$

Therefore, for a reaction to be spontaneous ΔH has to be negative and

$$|\Delta H| > |T\Delta S|$$

- Adsorption is an exothermic process: -Adsorption process takes place by adsorbate getting adsorbed on adsorbent. Forces of attraction exist between adsorbate and adsorbent and due to these forces of attraction, heat

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energy is released during adsorption. So adsorption is an exothermic process. [1]

E. Types of Adsorption: -

Forces of attraction exist between adsorbate and adsorbent. These forces of attraction can be due to Vanderwaal forces of attraction which are weak forces or due to chemical bond which are strong forces of attraction. On the basis of type of forces of attraction existing between adsorbate and adsorbent.

Adsorption can be classified into two types: -

- Physical Adsorption or Physisorption: -When the force of attraction existing between adsorbate and adsorbent are weak Vanderwaal forces of attraction, the process is called Physical Adsorption or Physisorption. Physical Adsorption takes place with formation of multilayer of adsorbate on adsorbent, it has low Enthalpy of adsorption i.e. ΔH adsorption is 20-40 KJ/mol. It takes place at low temperature below boiling point of adsorbate. As the temperature in, process of Physisorption decreases.

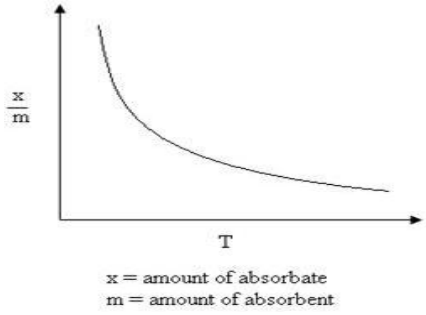

Fig. 7. Physical adsorption vs. Temperature graph

- Chemical Adsorption or Chemisorption: - When the force of attraction existing between adsorbate and adsorbent are chemical forces of attraction or chemical bond, the process is called chemical adsorption or chemisorption. Chemisorption takes place with formation of unilayer of adsorbate on adsorbent. It has high enthalpy of adsorption i.e.

$\Delta H_{adsorption}$ is 200-400 KJ/mole

It can take place at all temperature. With the increase in temperature, Chemisorption first increases and then decreases. [1]

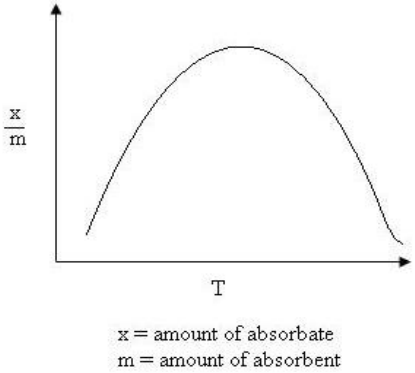

Fig. 8. Chemical Adsorption vs. Temperature Graph

F. Factors on which Adsorption depends

I. Temperature: -

Adsorption increases at low temperature conditions.

$$A + B \leftrightarrow AB + Heat$$

Adsorption process is exothermic in nature.

II. Pressure: -

As depicted by Adsorption Isotherm, with the increase in pressure, adsorption increases up to a certain extent till saturation level is achieved. After saturation level is achieved no more adsorption takes place whatever the pressure is applied.

III. Surface Area: -

Adsorption is a surface phenomenon therefore it increases with increase in surface area.

IV. Activation of Adsorbent: -

Activation of adsorbent surface is done so as to provide more number of vacant sites on surface of adsorbent. This can be done by breaking solids crystal into small pieces, heating charcoal at high temperature, breaking of solid into powder or other methods suitable for particular adsorbent. [1]

G. Examples of Commercial Adsorbents: -

I. Activated Carbon (Charcoal)
II. Silica Gel
III. Zeolites
IV. Activated Alumina
V. Polymers and resins
VI. Clays (Acid treated and pillared

H. CO_2 Emissions Facts and Figures (Globally): -

Table No. 1. Worldwide Emission of CO_2 [17]

Sr. No.	Country	CO_2 Emi-ssion in %	CO_2 Emission in Billion Tones	Estimated Year
1	China	46.54	11	2006-2020
2	U.S.	24.54	5.8	2005-2020
3	India	11.00	2.6	2005-2020
4	Russia	8.46	2	1990-2020
5	Japan	35.92	1.4	2005-2020
6	Germany	3.54	0.836	1990-2020

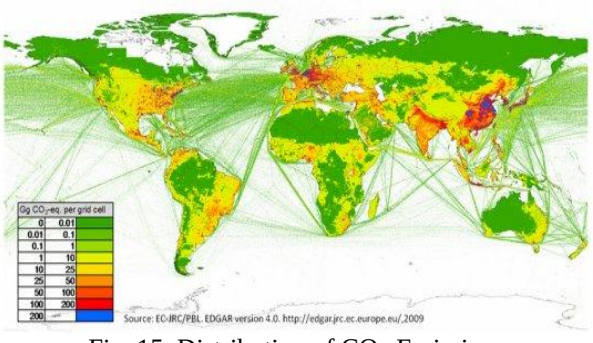

Fig. 15. Distribution of CO_2 Emission

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I. Summary of Major Motorcycle Emission Regulation in India: -

Table No. 2. Emission Standards History for Motorcycle Vehicles [18]

Sr. No.	Vehicle	Carbon Emission (g/km)	Effective Year
1.	All MCs	2	2000
2.	All MCs	1.5	2005
3.	All MCs	1	2008/2010
4.	All 2-Wheeler	1	2010
5.	Class 1 and Subclass 2-1[3]	1.4 3	2016/2017

J. Objectives: -

The objectives of our project is: -

I. To minimize the level of CO2 in the environment.
II. To adsorb CO and CO2 from exhaust gases of a two-wheeler.
III. To determine the CO2 removal efficiency through the bed of charcoal powder.
IV. To prepare an eco-friendly and cost efficient adsorption model which can selectively reduce carbon level from the exhaust gases of automobiles.
V. To make a handy pollution control device for convenient and comfortable traveling for bike.

V. LITRATURE SURVEY

I. Environmental Effects of Vehicle Exhaust Global and Local Effects- A Comparison between Gasoline and Diesel: -

In the above paper there is a comparison between two fuel exhaust system i.e. Gasoline and Diesel. When gasoline burn it produce carbon monoxide(CO), hydrocarbon(HC), carbon dioxide(CO2) and polycyclic aromatic hydrocarbon(PAHs) and when diesel is burn it produce nitrogen oxides(NOx) and particulate matter(PM). The result shows this paper is that burning gasoline and diesel fuel and to determine which fuel and its developed forms are less harmful to humans and which are most suitable for the environment. Gasoline fuel generate about 50% more CO2 than diesel fuel, and it also emit about ten times more CO, PAHs and around five times more HC than diesel fuels; burning diesel fuel will produce less CO2 emission than gasoline fuel, but will produce around ten times more NOx and PM than gasoline fuels. It also suggest that using a gasoline fuel in urban areas might help to reduce the human health effects and using the diesel fuel on motorways or in rural areas might help to reduce greenhouse gases(GHG) emission and minimize the global warming effect. Considering the diesel fuel exhaust emission NOx and PM are the two major problems. CO, CO2 and HC of diesel fuel exhaust emission are much lower than gasoline fuel counterpart. Due to the higher fuel economy and less the emission, diesel vehicle take a more and more important role in world auto mobile market. [10]

II. Adsorption of CO_2 on Activated Carbon: -

Activated carbon was a highly micro porous material with a large surface area. Activated carbon was used as one of the main adsorbents for desulfurization. There are four carbon sample A, B, C and D were used in this study. Sample A was a commercially activated carbon sample B, C and D were prepared by raw materials that were impregnated with different solution. Adsorption experiments of co_2 gas were carried out in a glass vacuum system. A comparison of the heat of adsorption on four carbon sample as in following order.

Sample B < sample A < sample C < sample D

In result show that the adsorption of co_2 on the four carbon sample does not follow the same adsorption isotherm equation. The Dubinin-Radushkevich (D-R) equation was found to fit well the adsorption data on carbon sample A and B. The freundlich equation was found to give the best fit for the adsorption on carbon sample C and D. The volumes adsorbed on the modified carbon samples B, C, and D were all larger than that on the raw carbon sample A. [11]

III. Kinetic Studies on Carbon Dioxide Capture Using Activation Carbon: -

In this paper there is the preparation of different agro-waste based activated carbon like Palm Fiber, Palm shell, Rice husk, Coconut shell, Coconut fiber. The formula for the CO2 adsorption is

$$Wt\ (mg) - Wo\ (mg) / Wo\ (mg)$$

Where,

Wt - Mass of absorbent at time t.

Wo - Original mass of adsorbent.

The rate of CO2 adsorption gradually Decrease with contact time, until an equilibrium condition was achieved. The kinetic analysis establishes an adsorption uptake rate and determine the residence time for the adsorption process to be completed. The formula for the kinetic analysis is

$$\text{Log } (qe - qt) = \text{Log } (qo) - (k_1 / 2.303)\ t$$

Where, 'qo' and 'qt' are the adsorption capacity (mg/g) at equilibrium and a time t

'K_1' is the rate constant of pseudo-first order model (1/min).

In this paper we found low cost activated carbon can be produced from the coconut waste is the larger carbon content and low in inorganic content it is used for minimize the waste production. The magnitude of activation energy which is lesser than 40 KJ/mole indicates on occurrence of the Physisorption mechanism. Besides, the kinetic analysis demonstration that the CO2 adsorption onto the activated carbon obeys the pseudo second order model. [14]

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IV. Catalytic converter: -

Fig. 16. Three-way catalytic converter on a gasoline - powdered.

A catalytic converter is an emissions control device that converts toxic pollutants in exhaust gas to less toxic pollutants by catalyzing a redox reaction (oxidation or reduction). Catalytic converters are used with internal combustion engines fueled by either petrol (gasoline) or diesel including lean-burn engines as well as kerosene heaters and stoves

The first widespread introduction of catalytic converters was in the United States automobile market. To comply with the U.S. Environmental Protection Agency's stricter regulation of exhaust emissions, gasoline-powered vehicles starting with the 1975 model year must be equipped with catalytic converters. These "two-way" converters combined oxygen with carbon monoxide (CO) and unburned hydrocarbons (HC) to produce carbon dioxide (CO_2) and water (H_2O). In 1981, two-way catalytic converters were rendered obsolete by "three-way" converters that also reduce oxides of nitrogen (NOx); however, two-way converters are still used for lean-burn engines.

Although catalytic converters are most commonly applied to exhaust systems in automobiles, they are also used on electrical generators, forklifts, mining equipment, trucks, buses, locomotives and motorcycles. They are also used on some wood stoves to control emissions. This is usually in response to government regulation, either through direct environmental regulation or through health and safety regulations. [16]

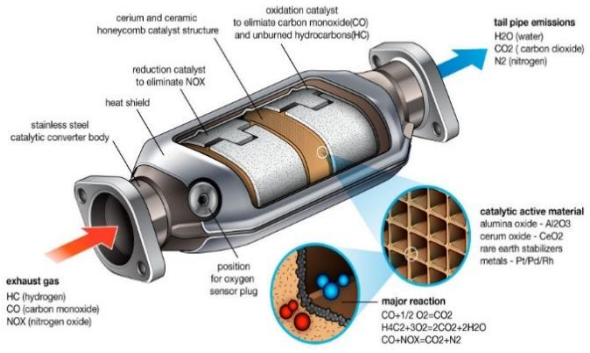


Fig. 17. Detail view of Catalytic converter

VI. MATERIALS & METHODS

I. Materials: -

Required materials for designing model: -

1. C.R. Sheet (Cold Rolled Steel Sheet)

Size: - 2 Sheets of 40×60 cm dimension
2 Sheets of 40×18 cm dimension
2 Sheets of 60×18 cm dimension
2 Sheets of 40×18 cm dimension (with no. of 1mm holes)

2. Joints
1 Nipple -1 inch
1 Nipple -1.5 inch
1 Elbow- 1.5 inch
3 Elbow-1 inch

3. PVC Pipes

Suitable length & diameter

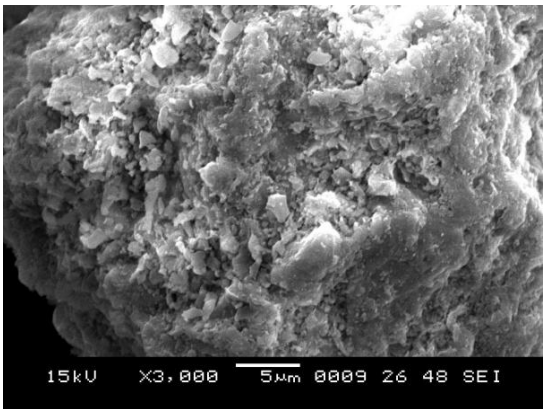
4. Rubber Gasket Plates (Size: 10×10 cm)
5. Screws
6. Spray Paints
7. Adhesives & Sealing Agents
8. Medicated Cotton

Required Materials for Adsorption: -

Charcoal: - Surface Area- Approx. 1300 m^2 (14000 sq ft) per gram

Diameter- Approx. 2-5 µm

SEM Reports: -



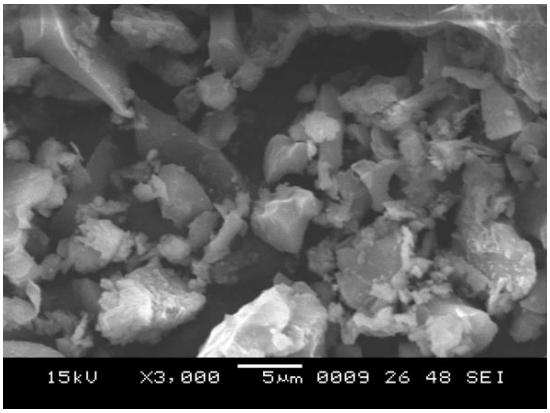


Fig. 18. SEM Report images

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II. Methods: -

Pollution Under Control (PUC) Certification system [3]

The first initiative to regulate vehicle emissions in India started in the year 1989 when Ministry of Environment & Forests constituted an expert committee to notify the emission standards for both new and in-use vehicles under the Environment (Protection) Act.

Table no. 3. First PUC norms in India. [19]

Type of Vehicle	Emission	Limit
Gasoline 4 wheeler	CO	3 %
Gasoline 2 / 3 wheeler	CO	4.4 %
Diesel vehicle	SMOKE	65 HSU

Note: HSU – Hartidge Smoke Unit

The in-use vehicle emission norms have been tightened with effect from 1st October 2004 and computerization model for emission check has been developed by Society of Indian Automobile Manufactures (SIAM), which is already in place in the major metro cities, same is depicted in Fig.17.

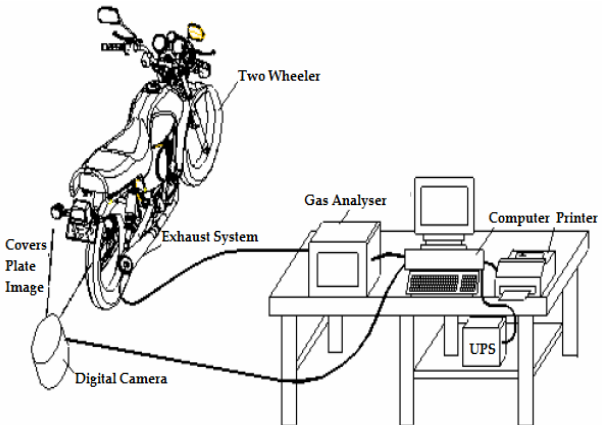

Fig. 19. Computerized PUC system

The LAMBDA (dimensionless value representing burning efficiency of engine in terms of the air / fuel ratio in the exhaust gases) measurement and tighter emission norms for in-use vehicles with such priority as may be warranted, after ensuring that gas analyzers capable of measuring the values, duly approved by the testing agencies, are available in the city or area, is proposed to be introduced in the respective state or union territory for vehicles provided that in case of petrol vehicles fitted with three way closed loop catalytic Converters operating in a specific city or area like Delhi.

Pollution under Control (PUC) Norms for in-use Petrol/CNG/LPG vehicles were notified by MoRT & H for implementation throughout the country from 1st October 2004, to comply with the idling emission standards for CO and HC in case of petro vehicle and smoke density for Diesel vehicles are given in Table no.4.

Table No. 4. PUC Norms for in-use Petrol / CNG /LPG driven Vehicles. [19]

Vehicle Type	CO (%)	HC (ppm)
2&3 wheelers (2/4 stroke) (vehicles manufactured before 31/3/2000)	4.5	9000
2&3 wheelers (2- stroke) (vehicles manufactured after 31/3/2000)	3.5	6000
2&3 wheelers (4 stroke) (vehicles manufactured after 31/3/2000)	3.5	4500
Bharat Stage -II compliant 4 wheelers	0.5	750
Four wheelers other than Bharat Stage -II compliant	3.0	1500

* For CNG and LPG vehicles the measured Hydrocarbon value shall be converted using the following formula and then compared with the limits

• For CNG Vehicles- Non Methane Hydrocarbon (NMHC) = 0.3 X HC

• For LPG Vehicles- Reactive Hydrocarbon (RHC) = 0.5 X HC

The Safety Regulations are being aligned with the Economic Commission for Europe (ECE) regulation and the Road Map prepared by SIAM envisages alignment by 2010. The SIAM has developed a computerized emission checking system for improving the credibility of the emission test system. In this system the Gas analyzer is connected to a Computer, which has a printer and a web Camera. The emission values from the Gas analyzer is sent directly to the computer and the photograph of the registration number plate of the vehicle is also captured. The emission data generated is stored in the computer, which is sent periodically to the Transport Department.

VII. EXPERIMENTATION

I. Design: -

Total Volume: - L×B×H ≡ 60×18×40 cm

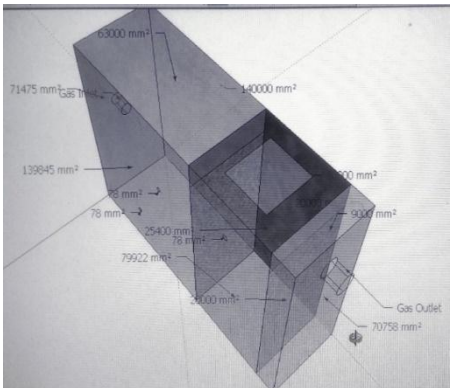

Fig. 20. Adsorption System (Detail View)

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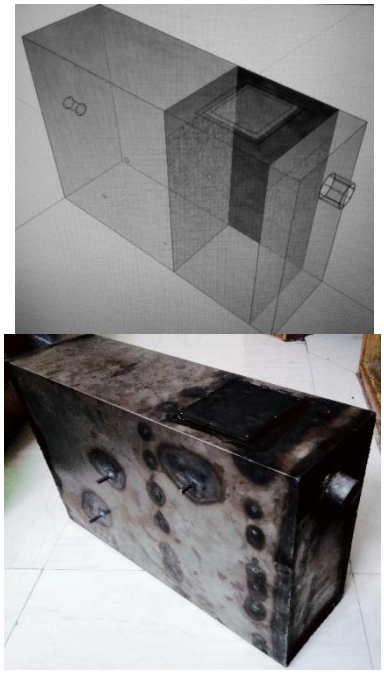

Fig. 21. Adsorption System (Plain View)

II. Experimental Setup: -

1. System consists of three compartments: -
a) Gas Inlet Section (35×18×40) cm
b) Charcoal powder Section (20×18×40) cm
c) Gas Outlet Section (5×18×40) cm.
2. System made up of CR (Cold Rolling Steel) Sheet which is fabricated by welding process to avoid leakages.
3. The inlet pipe and outlet pipe are of 1 inch and 1.5-inch diameter respectively.
4. Barriers between each compartments are made up of highly porous CR Sheet having holes of about 1mm diameter.
5. Medicated Cotton is used to hold the charcoal inside charcoal compartment and it do not permit the particles of charcoal powder to flow with Exhaust gas.
6. An opening of 10×10 cm is made over the charcoal compartment to feed and eject the charcoal powder.
7. From which saturated charcoal can be taken out from the system for again activation purpose or use as a fertilizer into soil for promoting Plant Growth.

III. Experimental Run or Procedure: -

1. Take PUC analysis of Exhaust gas of bike before attaching the system to bike's exhaust.
2. Attach the system to the exhaust of bike by provided riveted joints and connect the inlet of system to the outlet of silencer of bike.
3. Start the bike.
4. Run the bike for particular distance, the exhaust gases will release from the engine to silencer of bike.
5. These gases passed through the inlet of system into 1st compartment of the system which was kept empty.
6. The gases will start to collect in the empty compartment (1st compartment) of system and pressure will start to increase in the 1st compartment.
7. Then due to this pressure, the gases start to pass through the bed of charcoal powder (2nd compartment) where adsorption of CO and CO_2 takes place.
8. After adsorption of CO and CO_2 from the inlet gases, remaining gases come out into 3rd compartment.
9. At this stage again take analysis of exhaust gas which will coming out from outlet of system and compare the results.

IV. Cost Estimation: -

1)	Fabrication + Material cost	: □ . 2500
2)	Charcoal (10 Kg)	: □ . 100
3)	PUC Analysis	: □ . 200
4)	Fuel	: □. 100
5)	Total cost	: □ . 2900

V. Advantage of Model: -

- Our project is helpful in preventing CO2 release into the environment which is a major GHG.
- It is useful in CO2 capturing which has significance on land, i.e., in farms, in industries.
- It is a good air pollution control option.
- A person using this device would be listed in responsible citizens' category contributing to pollution control as well as to nation's welfare.
- It is less expensive technique as compared to others.

VI. Disadvantage of Model: -

- The device may look little big on a Two-wheeler.
- The person seating on the back seat may feel uncomfortable during travelling.
- Extra money need to be spent which may be a burden for people.
- Another problem may arise in the form of periodic replacement of saturated charcoal.

VII. RESULT AND DISCUSSION

Experimental results on Run: -

Table No. 5. Actual experimental results (% Removal of CO & CO_2)

Sr. No.	Components in Exhaust gas	Values (ppm & vol. %) Before Run	After Run	Impurities Decreases (%)	Components increases (%)
1.	CO_2	9.83	7.83	20.35	-
2.	CO	4.720	2.545	46.08	-
3.	SHC	574	700	-	21.95
4.	O_2	2.61	6.19	-	137.17

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1) After comparing the analysis of Exhaust gas before and after assembling system, the efficiency of CO_2 adsorption of charcoal is found out to be 20%.
2) The type of adsorption on charcoal is physical adsorption i.e. the adsorption is reversible type of adsorption.
3) The difficulty comes in the form of charcoal fluidization inside the compartment.
4) Ultimately, we can say that due to less adsorption or less mass transfer. We are getting the result which is below our expectation.

IX. CONCLUSION

We know that adsorption is a complex phenomenon to study as compared to distillation, absorption and many more unit operations but this process has adequate potential to dominate in pollution control techniques because if charcoal powder is used as an adsorbent then we can reduce the overall cost dramatically. Our research is absolutely focused on CO and CO2 reduction from exhaust gases of a two-wheeler by adsorption using charcoal powder. For this purpose, we have designed the adsorption based model which is easily attachable to the exhaust section of a two-wheeler and is aspired to bring revolution in the field of vehicular pollution emissions and control. Although, we got less CO & CO2 removal (20% only) during our experimentation but it enlightens us with the remedies and solutions that can be applied in reduction of CO2 from exhaust of automobiles. Lastly, we conclude by saying that our technology is helpful for society by minimizing carbon release from vehicles into the environment. It is also a brilliant topic for further research and development.

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